An Extract of Letters from Dr. John Wallis *to the Publiſher,* 1672. Sept. 26. &c. *concerning the Suſpenſion of Quickſilver well purged of Air, much higher than the ordinary Standard in the Torricellian Experiment.*

SIR,

I Am not ſorry to find, in your *Tranſactions* for the laſt Month, (which I have newly received,) that M. *Hugens*, an Ingenious and Inquiſitive perſon, doth endeavour to give a Reaſon of that Odd *phænomenon* in the Torricellian Experiment (obſerv'd by my Lord *Brouncker*, and Mr. *Boyle*, many years ſince, in purſuance of an Order of the *R. Society* to that purpoſe,) of which I give an account in my Treatiſe *De Motu Cap.* 14. *Schol. prop.* 13. The Phænomenon is this:

Whereas in the Torricellian Experiment, the Quickſilver contain'd in the Inverted Tube, how long ſoever, whoſe open orifice C. is immerged in ſtagnant Quickſilver, does uſually fall down to the height of about 29. inches above the ſurface of the ſtagnant Quickſilver AB, and there remains ſuſpended, as at I: If the Quickſilver be well cleans'd from Air, it has beed found to ſtand top-full, much higher, even to the height of 75. inches (and how much higher it may ſtand, we cannot tell;) but upon the admiſſion of the leſt Air, or a concuſſion of the Tube, it falls down to the uſual ſtandard.

Two Reaſons I did there hint (though not perfectly ſatisfied in either:) The *one*, of my own, concerning the Spring of the Air, neceſſary to put Heavy bodies in motion, not impell'd by any other force: The *other*, of my L. *Brouncker*, that there might be in the Air yet a greater Weight or Preſſure than is neceſſary for the height of 29 inches, in caſe there be nothing but the bare weight of Quickſilver to be ſupported.

I find, Monſieur *Hugens* to fall in with that of my Lord *Brouncker*, ſave that what we comprehend under the name of *Air*, he calls a *more ſubtile Matter:* which alters not the Caſe at all, but only the Name.

By *Air*, I find, Mr.*Hobbes* would ſometimes (as in *Dialogus Phyſicus* p. 4.) have us underſtand a *pure Æther*, or (as his words are) *Aerem ab omni Terræ Aquæq; effluviis purum qualis putatur eſſe Æther*; to which, I ſuppoſe, anſwers the *Materia ſubtilis* of *Des Cartes*, and Monſ.*Hugens* his *more ſubtile Matter* than *Air*. On the other hand, M.*Hugens* here, by *Air*, ſeems to underſtand that feculent matter ariſing from thoſe the *Earths and Waters Effluvia*, which are intermingled with this *ſubtile Matter*. We mean by *Air*, the *Aggregate of both theſe*, or whatever elſe makes up that *Heterogeneous Fluid* wherein we breath, commonly called *Air*; the purer part of which is Mr.*Hobbes*'s *Air*; and the feculent of it is Monſieur *Hugens*'s *Air*.

And therefore, where I ſpeak of *Vacuity* caus'd by the Torricellian Experiment, or ſuch other ways, I do expreſly caution (*De Motu C.* 14. and *Hobb. Heaut. p.* 152. and elſewhere,) not to be underſtood as affirming *Abſolute vacuity* (which whether or no there be, or can be in nature, I liſt not to diſpute;) but at leaſt an Abſence of that *Heterogeneous mixture which we call Air, ſuch as that is wherein we breath*; without diſputing againſt the *purus Æther* of Mr. *Hobbes*, or the *Materia ſubtilis* of *Des-Cartes* or M.*Hugens*; as not neceſſary to the Inquiries in hand.

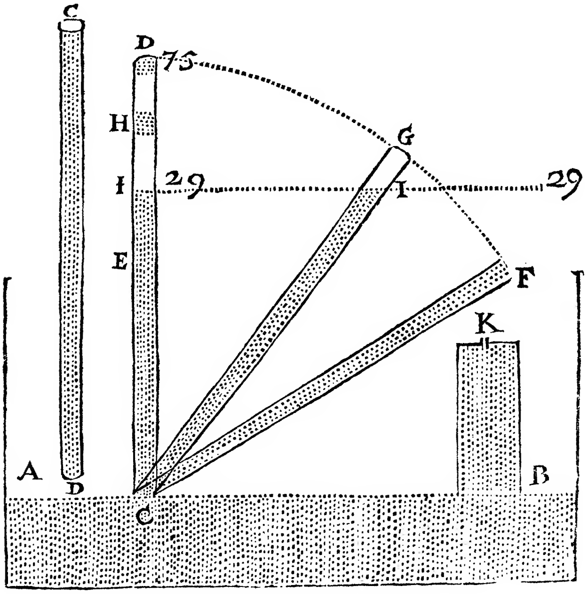
To the Preſſure of this Purer matter (which they ſuppoſe ſo ſubtile, as to penetrate the Mercury, Marble, and Glaſs it ſelf,) they adſcribe the Suſpenſion of the Quickſilver to ſo great an height. And my Lord *Brouncker* in particular, while that Piece of mine was under the Preſs, had a deſign (as He then ſignified to me) of proſecuting the Experiment (as Monſieur *Hugens* does now adviſe,) to ſee if he could bring it to ſome Determination (of which I might there have given an account, if it could have been diſpatcht time enough;) what were the utmoſt height at which it might be thus made to ſtand; thereby to determine the preſſure of this Purer matter, as that of the Common Air is determin'd by the Torricellian Experiment. But his leiſure not then ſerving, I only gave that brief account of his

Notion, as it is there inſerted: And, whether he have ſince had leiſure, amidſt a great preſs of other buſineſs, to purſue it, I am not certain.

Now, though I would not wholly exclude this, if ſuch ſhall be found to be (but only ſuſpend my Aſſent till it be evinced;) yet ſurely there muſt be ſomewhat more in it than that of this Subtile matter, to ſolve the *Phænomenon*, notwithſtanding the two Experiments now alledged by M. *Hugens* in favour of it. For, if this Matter be ſo ſubtile as to preſs, through the top of the Glaſs, upon the Quickſilver (and conſequently through the upper upon the neather of the *two-Marbles*,) as is acknowledged; (and without which it is no more able to precipitate the Quickſilver while impure, and when it is in part ſubſided, than when it is pure, and the Tube top full:) I do not ſee, why it ſhould not balance it ſelf (above and below) in the ſame manner as Common Air would do, if the Tube were pervious to it at both ends, and the Quickſilver, by the preponderance of its own weight, fall preſently.

And the *Anſwer*, That, though the Glaſs be penetrated by it, yet not in ſo copious a manner as where no Glaſs is; doth not, to me, ſolve the difficulty: Becauſe the ſame obſtacle doth juſt in the ſame manner remain, when the Tube is in part emptied; and, when the Quickſilver is un-purged: the pores of the Glaſs not being, by either of thoſe, made more open or more pervious. And if we ſuppoſe the Subtile matter by percolation to be ſtrain'd through, with ſome difficulty, (as Air or Water would be through a cloth,) this might poſſibly cauſe the Quickſilver, when it does ſink, to ſink *gradually*; but not (as we ſee it,) *ſuddenly* to fall to the height of 29 Inches; as from D to I.

The Connexion or Cohæſion of the parts of Quickſilver, either each to other, or to the ſides of the Glaſs, which Mr. *Hugens* ſuppoſeth to require for their ſeparation a greater force, than is in theſe percolated particles till they have room made for them to combine; ſeems to me the leſs conſiderable, becauſe it is not ſo neceſſary to ſeparate them from each other, ſince that they may un-ſeparated ſlide down by the ſides of the Glaſs; to which, it is well known, and viſible to the eye, the Quickſilver is not at all apt to ſtick, but doth rather decline that contact; in like manner as we find Water not apt to Joyn with Oyle or Greaſe; though Water to Glaſs, and Quickſilver to Gold, do very readily apply themſelves. So that there needs no ſuch Force to diſjoyn the Quickſilver from the Glaſs, whatever there may be for diſ-joyning its parts one from another.



If therefore we ſhould ſuppoſe the preſſure of the *Groſſer* Air downwards on AB (the ſurface of the ſtagnant Quickſilver,) and conſequently, by means thereof, upwards at C, ſufficient only to bear up that in the Tube to the height of I; but the ſuper-added weight or preſſure of the *Purer* Air to hold it up as high as D (75 inches or more,) while it is full, and the Quickſilver well cleans'd; as if ſo long it could not enter at D; but in caſe it be not ſo cleanſed, or be already ſunk to H, this *purer* Air would enter at D, and thruſt it downto I, counterballancing the preſſure (at C) of the purer but not of the groſſer Air (which I take to be the ſum of the Cauſe aſſign'd by M. *Hugens* :) I am yet to ſeek, why it may not as well penetrate D at firſt to begin the Deſcent, as afterwards to purſue it; and, why not as well begin the Deſcent when the Quickſilver is well cleanſed of Air, as when it is not ſo; and why alſo, if the *pure* Air do freely enter at D, it does not preſently fall; or, if not freely, why, when it does fall, it falls ſuddenly and not leiſurely from D to I; eſpecially ſince ſo ſmall a weight as D H of pure Air (for the groſſer cannot enter,) is very inconſiderable; if not at all, or not freely, preſſed by *that* incumbent on D; and the Adheſion not conſiderably leſs, by being ſeparated only at the Top, while it yet continues to touch the ſides.

I am apt therefore, as heretofore, to adſcribe the *Cauſe* of this *Phænomenon* to the Spring that is in Air, and the want thereof in Quickſilver. For, that in Air there is a Spring or Elaſticity, is now undoubted; but in Water, cleans'd of Air, though many Experiments have been attempted to that purpoſe, it has not yet been found that there is any: And I am apt to think the like of Quickſilver; though I do not know, that this has been yet ſo rigorouſly examin'd. Now ſuppoſing, that Matter, being at Reſt, will ſo continue till it be put in motion by ſome Force; this force may be *either* that of *Percuſſion* from ſome Body already in motion (which is the Caſe, when the Quickſilver falls by ſhaking or ſtriking the Tube;) *or* of *Pulſion*, from a contiguous Body beginning to move, as by the Expanſion of ſome adjacent Spring (which is the Caſe, when the Springy parts of the Air, either left in unpurged, or re-admitted in the Quickſilver, by expanding themſelves put the Quickſilver in motion;) *Or* ſome *Conatus* or Endevour of its own; ſuch as is that of a Spring (from whatever cauſe it be, which I do not here inquire,) but has place only in Springy bodies; and therefore if Water and Quickſilver be not ſuch, they will not on this account put themſelves in motion.

Gravity or Heavineſs is, I know (if we knew what it were,) reputed to be ſuch a *Conatus* or Pronity to move downwards, and ſo to put it ſelf in motion: And the wonder at preſent is, why it does not ſo here. But if this, which we call *Gravity*, ſhould chance to be not a Poſitive quality or *Conatus* originally of it ſelf, but only the Effect of ſome Pulſion or Percuſſion from without, (which poſſibly may be the Caſe, and principally from the Spring of the Air about us;) then, while this Pulſion and Percuſſion is wanting (however obviated,) the Bodies, accounted Heavy, will not of themſelves begin to fall: which ſeems to be the preſent Caſe.

And this is the more conſiderable, becauſe we cannot (at leſt not yet) find, what is the Utmoſt height at which the Quickſilver thus accumulated will remain ſuſpended; there having been (for ought I know) no height yet attempted, at which, if cleanſed, it will not ſtand; and that of 75 inches, conſidering the weightineſs of Quickſilver, is a very great one, being more than equivalent to 80 foot of water.

My Lord *Brouncker* doth a little alter the caſe, from what I take to be the Hypotheſis of Monſieur *Hugens*. For he ſuppoſeth this *purer* part of the Air to be of like nature with the *groſſer* part, (which I think M. *Hugens* doth not;) and, though finer than the reſt, ſo as to penetrate Glaſs, which the groſſer will not (there being in all ſorts of grains, ſome greater than others, and which will not paſs ſo fine a Sieve;) yet of a Springy nature, as the *groſſer* parts are: Which therefore acts, not by its *Weight* only, but by its *Spring*; and therefore when once entred, though in a ſmall proportion, acts as effectually, at its firſt entrance, as if the whole incumbent Air had admiſſion; its Spring being of a like tenſure with that of the outward Air; (as I have heretofore ſhewed *Cap.* 14. *De motu prop.* 11, 12, 13:) But M. *Hugens*'s more Subtile matter than Air though he muſt allow it Weight (for elſe its entrance would be nothing to the purpoſe,) yet whether he allow it a Spring, I cannot tell; nor doth he inform us. And when he ſays, this more Subtile matter than Air doth without difficulty penetrate Glaſs, Water, Quickſilver, and all other bodies, which we find impenetrable to Air; I know not whether he mean, without *any* difficulty (as the words ſeem to import,) or (as I conjecture by what follows) without *great* difficulty, though with *ſome.*

But his Lordſhip (if I miſtake not) though he allow his (Springy) Subtile matter to penetrate Glaſs, yet not without difficulty; and, till it have ſome room made (as HD) wherein it may recollect it ſelf, cannot exert its Spring, and therefore not while top-full of cleanſed Quickſilver; but, ſo ſoon as ſome room is made for it: Whereas, if the Quickſilver be not purged of Air, that little Air remaining doth by its Spring begin the motion.

He thinks it alſo not improbable (and if it ſo prove, it will be a good confirmation of this *Hypotheſis,*) that a large but low Tube of Glaſs (ſhorter than 29 inches) may ſtand top-full of Quickſilver, though with a ſmall hole in the Top, as at K; at leſt, if immerged in Water, in caſe Air be too Subtile for our Mechanicks.

He might alſo, ſuitably enough to his own Hypotheſis, have ſo explained himſelf, as to allow his more Subtile parts of common Air to penetrate Quickſilver, but not Glaſs; and therefore, in caſe of room for it at HD, it might through the Stagnant Quickſilver, and that at C, paſs upwards to HD, and there exert its Spring.

I ſhall forbear to diſpute againſt this Hypotheſis for the preſent; becauſe I think it more proper to examine by Experiment (which I think hath not yet been done,) whether well-purged Quickſilver may not be made to ſtand higher than C I, the ordinary ſtandard, ſuppoſe at CH, with a void ſpace about it, as HD. For the iſſue of this Experiment (amongſt others to be after mentioned,) ſeems very proper for determining of this doubt; which therefore I am not willing to pre-judge. There is yet another way of explicating the ſame Hypotheſis, without allowing this Subtile matter to pierce the Glaſs; which is this:

Our common Air being an aggregate of very Heterogeneous parts, we may well ſuppoſe ſome of them to be Springy, and others not to be ſo. The Springy parts we may conceive to be ſo many conſiſtent Bodies, like ſmall hairs or ſpringy threads wrapped up in different forms and variouſly intangled, and ſo as to form many vacuities capable of admitting (what~~ſoever~~ other parts of the Air may be ſuppoſed to be) ſome Fluid matter, which may inſinuate into thoſe vacuities, (as water in a bundle of Buſhes,) without diſturbing the Texture of thoſe Springy parts; and which may preſs as a *Weight*, but not as a *Spring*, (of which diſtinction ſee *Cap.* 14. *De motu*, *Schol.prop* 11. & *Schol.prop.*13.*pag.* 729, 730, 732, 733.)

Now if, in the Torricellian Tube, there be a quantity of ſuch Springy matter, the Spring hereof will be of equal ſtrength with that of External Air, (and therefore able to counterballance it, though its weight be much leſs,) becauſe admitted with ſuch a tenſure, (*ibid.prop.*12.13) But if only an Un-ſpringy Fluid (which preſseth but as a Weight not as a Spring,) and this defended by the glaſs-Tube from any other preſſure, ſave that of its own weight; it will ſtill be too weak to force its own way, till its ſingle weight be equivalent to that with which it is to encounter; which is, not onely the Springy part of the Air, but alſo that Fluid Un-ſpringy part; which though (becauſe Fluid) it would give way to a Springy body preſſing through it; yet not to this Fluid, like it ſelf, and deſtitute of ſuch a Spring; and is therefore able to keep it up to a much greater height than it could do if un-cleanſed of Springy Air: So long at leaſt as till ſome Springy body be admitted, or ſome concuſſion, equivalent to it, put it in motion; but being once in motion, it will ſo continue (as a Bullet impell'd by Gun-powder, or an Arrow out of a Bow,) till ſtopped by ſome Poſitive force equivalent.

I do not deny, but that this explication may be ſubject to ſome Difficulties and Exceptions; but I think, fewer than that of allowing the Glaſs penetrable by this Subtile matter.

But the beſt way to ſettle this buſineſs, being ſome ſuitable Experiments; I ſhould recommend (becauſe I am not ſo well accommodated for this purpoſe,) theſe, or ſome of theſe, Experiments, to thoſe of the *Royal Society*, who are in that kind better provided than I.

1.(That hinted by my Lord *Brouncker*,) Whether a large low Tube, of leſs height than the common Standard (of about 29 Inches *Engliſh*, or 27 Inches *French*,) might be made to ſtand top-full of Quickſilver, though a ſmall hole be left open at the Top; at leaſt under Water? I am apt to think, that it will rather ſink ſlowly and with a hiſſing noiſe, than fall ſuddenly and ſilently.

2. Whether of two poliſhed Marbles or metalline Plates, the lower will be found to ſtick to the upper, in the exhauſted Receiver, longer than is accountable for from the ordinary Counter-ballance in the Torricellian Experiment. For though Monſieur *Hugens* now, and Mr. *Boyle* (if my memory do not much fail me) have long ſince intimated this from his own Experience; yet I judge the Experiment worth repeating. And if it be (as I ſuppoſe it may) found to ſucceed, I ſhould think it may proceed from a want of a Spring or Elaſtick power between the Plates to force them aſunder; and in particular (ſince with this it hath been tryed) that Spirit of Wine is not a Springy body.

3. Whether a Siphon of unequal Legs will be made to run, in an exhauſted Receiver, with Water or Quickſilver, at a greater height than is accountable for; which though Monſieur *Hugens* have tryed it, I think it worth repeating in this *Society*. This when it doth ſucceed, I take to proceed from the Spring of that little remaining Air in the Receiver not quite emptied.

4.(Which ſeems of a like nature with the former,) Whether a Tube of greater length than 29 Inches, but ſo immerg'd as to be leſs than ſo much above the level, as CE, may not, if filled with well cleanſed Quickſilver, be gently lifted up with the Quickſilver in it, not only to I (as when it is unpurged) but to H or D, higher than the uſual Standard.

5. (Which is equivalent, but more eaſily adminiſtred,) Whether if ſuch a Tube, ſo filled, be at firſt ſo inclined (as CF) that its height above AB be leſs than 29 Inches, may not be leiſurely and gently erected, ſo as to remain full, not only to the height of I, but of G or D?

6. Whether cleanſed Quickſilver will, in the open Air, run in a Siphon higher that 29 Inches?

7. If not in the Air, whether it will ſo run, if the lower Leg open into well-cleanſed Water?

8. (Which I do principally recommend;) In a Tube ſo filled with cleanſed Quickſilver, as to ſtand top-full at a greater height than the uſual Standard, as CD; in caſe ſome part be forced out, not by admiſſion of Air but by Jogging the Tube, (I ſuppoſe as much as HD,) and a ſtop then made: Whether the reſt CH (at a greater height than I, the uſual Standard,) may be made ſo to ſtand of it ſelf, notwithſtanding the voidance of HD? For by this Experiment alone, if it ſucceed, it will appear, that it is not onely want of room for the Subtile matter to recollect it ſelf, which hinders the ſuſpended Quickſilver from falling; but rather (unleſs ſome probable cauſe can be found,) the want of a Spring to put it in motion. If it will not ſucceed, I ſhould rather think, the Springy Air doth make its way through the Quickſilver than through the Glaſs.

9. Whether cleanſed Quickſilver will remain ſuſpended in an inverted Tube (at leaſt a ſhort one, and with a ſmall Orifice,) though its Orifice C be no immerg'd in Quickſilver, but either in the open Air, or at leaſt in Water?

10. If ſo; then whether it will do the like, if, a little being forced out, there be ſome void room left at the Top, at HD?

Theſe are nice Experiments, and of ſome difficulty; but if carefully adminiſtred, may be of good uſe in our ſearch after the true nature of *Gravity*: Which may poſſibly have a greater connexion with the Spring of the Air, than men are aware of; ſince on the preſence or abſence thereof doth mainly depend the falling or not falling of

Bodies accounted Heavy. But I am not willing, by interpoſing my own Conjectures, to pre-judge the Experiments.

An Account of Two Books.

I. *Obſervations Topographical, Moral and Phyſiological made in a Journey through part of the* Low-Countries, Germany, Italy *and* France, *by* John Ray, *Fellow of the R.Society: Whereunto is added a Brief Account of* F.Willoughby *Eſq; his Voyage through a great part of* Spain. London, *printed for* J.Martyn, *Printer to the R.Society, at the Bell in St.* Pauls *Churchyard*, 1673. *in* 8°.

This Curious and very Inſtructive *Itinerary* may well ſerve as a Pattern for Travelling with that improvement and advantage, as ought to be aimed at by all diſcreet Travellors; as containing whatever is remarkable both for Perſons and Things in thoſe places, which the Ingenious and Inquiſitive Author together with his good Company travelled through. Let his Reader be a States-man, an Eccleſiaſtick, a Philoſopher, an Artiſt, a Trades man, a Father of a Family, an Huſband-man, they will all of them find matter in this Book very proper for their reſpective Genius, Profeſſions and Callings. Here is deſcribed the Climat, Government, Revenues, Laws, Cuſtoms, Manners, Tempers, Abilities, Studies, Arts, Trades, and Natural Productions of the Countries ſpoken of; and beſides, divers Fabulous relations and ungrounded fancies refuted and rectified.

We ſhall only hint in this place the principal Heads of ſuch particulars, as belong to the purpoſe of *theſe* Tracts; in reference to which is to be noted what the Author obſerves,

1. Of the ſeveral Conſtitutions of Climats, and the difference, he found, between the Temperature of the *Air* on two oppoſite ſides of ſome Mountains.

2. Of *Waters*, as the moſt conſiderable Rivers and the Fiſhes bred therein; Of Springs, (the Original of which he diſcuſſeth,) ebbing and flowing Wells, *Spaw*-waters (particularly